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DETROIT

Electron Tube Information Service

THE National Bureau of Standards has established a tube information service for accumulating and disseminating technical data on both domestic and foreign radio tubes. At the present time nearly 10,000 cards, filed by tube type number, are appropriately referenced to manufacturers' source material. In addition, about 10 percent of these cards, selected mainly from the high-use miniature and subminiature types, have been coded on punched cards for mechanical sorting.

With this unique service, it is possible to find (1) information about any particular tube, (2) all tube types whose electrical characteristics, bulb sizes or base configurations fall within particular ranges, and (3) domestic tubes that can be substituted for unavailable foreign tubes. The program began about 7 years ago as a service to NBS personnel. It has since been extended to all scientists and engineers in Government and industry who have legitimate requests and was recently expanded to include junction diodes and transistors. This continuing service is being carried out by C. P. Marsden and J. K. Moffitt of the Bureau's electron tube laboratory.

The NBS tube information service was established to meet the ever-increasing number of requests for information that was not readily available on little-known tubes or tubes of foreign manufacture. As the service grew, it included more and more detailed information on larger numbers of tubes. Recently the Bureau has begun punched-card coding for automatic selection in order to process requests more rapidly. The goals of the service are to include the latest technical data on all domestic and foreign tube types and to have all such information coded.

The service includes all such data on electron tubes and semiconductor devices as electrical characteristics, bulb size and base configurations, ambient operating conditions, and where possible, construction details. The main source of this information is the manufacturer's brochure or handbook. While the major companies automatically furnish the information through their distribution lists, numerous new and small companies must be queried directly whenever preliminary information on their products is gathered from advertisements, articles, and brochures. Special attention to these scattered sources has been required to maintain current the file on crystal diodes and transistors. The NBS files include products of about 80 domestic and 15 foreign manufacturers. In general, foreign data has been limited to Western European sources.

So far, the Bureau has received requests for tube information mainly from other Government agencies, the military services, foreign governments, and local private industries. Most of the inquiries have been for information about the electrical characteristics of a particular tube type or the selection of a domestic tube for replacement in foreign equipment. Although this sort of request is easily met, questions on cathode operating temperature or contact potentials must be answered in general terms because these quantities vary with the manufacturer. Queries on tube types with specified electrical, mechanical, or geometric character-

istics are usually answered by a combination of machine card sorting and reference research. Clearly, only general information can be coded on punched cards; after machine selection of several tubes that meet the specifications of the inquiry, reference research is required to supply the more specific information. In general, coding is on the basis of operating voltages, transconductance, etc.; and the tube types machine-selected are those within the ranges specified by the inquiry.

While the coding on punched cards has been completed only for the miniature and subminiature tubes with bulb sizes up to T6½, the Bureau plans to proceed as rapidly as possible with the coding of all other tube types. The semiconductor devices are being coded as the information becomes available.

Note: The Bureau's service is open to all who have legitimate requests. Inquiries may be made by telephone if desired. However, they should contain as much factual information as possible to expedite the reference research, and should include background information where appropriate. The service cannot undertake to answer queries on tube applications in circuits; complex or highly detailed questions that may require laboratory research can be answered only on the basis of data available. Address inquires to C. P. Marsden, Chief, Electron Tubes Section, National Bureau of Standards, Washington 25, D. C. Manufacturers are urged to supply the Bureau with technical information on new tube types as they are placed on the market, so that the service can include all the most recent data.

Coding classifications[a] of the tube types for the NBS tube information service

Function
- power amplifier
- converter
- detector
- voltage regulator
- voltage reference

Emitter type
- coated filament
- thoriated tungsten filament
- tungsten filament
- unipotential, coated
- dispenser
- cold cathode

Normal operating voltages
- grid
- plate
- screen
- suppressor

Suppressor
- brought out
- tied to cathode

Filament (or heater)
- voltage
- current

Current
- plate
- screen

General characteristics
- double cathode
- double-ended
- beam power
- sharp cutoff
- remote cutoff
- electrometer
- metal envelope
- guided missile
- hearing aid

Number of electrodes
Physical size
Frequency
Mutual conductance
Amplification factor
Plate resistance
Plate dissipation
Peak inverse voltage
Interelectrode capacitances

[a] At the present time, punched-card coding has been completed only for miniature and subminiature tubes.

Typical Requests for Information

Q: What are the American equivalents of the KT-66?
A: 6L6 WGA, 5932.

Q: What type deflection and focus do the following cathode ray tubes have?
A:

16ZP4	Magnetic focus and deflection.
17AP4	Magnetic focus and deflection.
17HP4	Electrostatic focus, magnetic deflection.

Q: What is designation of a subminiature having a high mu, and high Gm and is similar to 5744 WA?
A: 6151 is a near equivalent.

Q: What is miniature equivalent for the subminiature 6111?
A: 12AT7WA and 6201.

Q: What are plate current and Gm of the following types?
A:

	Plate current	*Gm*
5875	3.5 ma	2500 μmhos
5636	3.5 ma	1280 μmhos

Q: What are characteristics of the following crystal diodes and transistors?
A:

1N107 crystal diode	
Forward current at 1 v	150 ma min
Reverse current at 10 v	200 μa max
Peak inverse voltage	−15 v min
Maximum operating voltage	10 v max dc
1N67A crystal diode	
Peak inverse voltage	100 v
Continuous operating inverse voltage	80 v
Peak rectified current	90 ma
Surge current for 1 sec	350 ma
G–11 transistor	
Collector dissipation	100 mw
Collector voltage, V_c	30 v
Collector current, I_c	7 ma
Emitter current, I_e	3 ma

Q: What is the frequency and wavelength range of the light output of a glow modulator R1130B?
A: Modulating frequency range 15 to 15,000 c/s
Useful light range 3500 to 7200 Angstroms

Q: Is the 25B5 still being manufactured? What is a replacement for it?
A: The 25B5, which had a 6-pin base, is no longer being manufactured. It can be replaced by the 25B6, 25C6, 25L6GT, or 25N6, all of which have octal bases.

Sixth National Conference On Standards

MORE than 800 representatives of Government and industry attended the Sixth National Conference on Standards in Washington, D. C., October 24–26. Based on the theme, "Government-Industry Cooperation in Standardization," the Conference was jointly sponsored by the National Bureau of Standards and the American Standards Association. The Conference brought together leaders and specialists to discuss problems and progress in the field of standardization—from its legal implications to defense and industry requirements for manufactured products.

Dr. A. V. Astin, Director of the National Bureau of Standards, opened the Conference with an address in which he cited the long cooperation that has existed between NBS and industry.

Progress in standardization was epitomized by an announcement of Vice Admiral George F. Hussey, Jr., USN (Ret.), Managing Director of ASA. At the opening session which constituted the 37th Annual Meeting of the ASA, he told the delegates that the 1500th American Standard had just been approved.

This figure is double the number of American Standards in use in 1948.

In the conference keynote address, Thomas P. Pike, Assistant Secretary of Defense, Supply and Logistics, urged American industry to develop a truly comprehensive set of national standards. This can only be done, he said, by close cooperation of Government and industry in standards work. He pointed out that increased standardization in producing weapons and their military hardware would save taxpayers large sums of money, and added that more industrial standardization is a vital defense need. Without it, he said, the national safety will be jeopardized. Assistant Secretary Pike also stated that the United States is rapidly becoming a "have-not nation" in a number of raw materials and warned that we cannot continue to waste them simply because we lack nationwide performance standards that would encourage use of alternates to scarce materials.

Lowell Mason, Federal Trade Commissioner, and Ephraim Jacobs, Chief of the Legislation and Clearance Section, Justice Department Antitrust Division, noted that standardization has been an important factor in industrial progress. Mr. Jacobs informed the Conference that the Justice Department's main concern with respect to standardization is that it not be used for illegal price fixing or to limit competition.

Some 200 delegates to the Sixth National Conference on Standards visited 12 laboratories selected to present a cross section of the Bureau. The group of delegates is inspecting an altitude chamber for studying flames at low pressures.

"Distinctive part numbering and distinctive marking of aeronautical standard items are musts," C. E. Mines, chief of engineering services, Allison Division of General Motors, and chairman, Aeronautics Committee, Society of Automotive Engineers, informed the Conference at a session devoted to Government-industry standardization at the Army, Navy, and Air Force level. "The product designers' know-how should be recognized as vital on changed parts just as it is now recognized on brand-new parts," he said.

Edmund F. Mansure, Administrator of the General Services Administration, reported that standardization of commodity requirements by GSA has saved the Government 15 percent of its previous costs in the fields standardized. By completing 58 projects on commodity standardization GSA has eliminated 85 percent of the items involved.

Development of common industrial and military standards among Britain, Canada, and the United States "as a means of survival of our people" was asked by James G. Morrow, The Steel Company of Canada, Ltd., who was presented the Standards Medal of the American Standards Association. Dr. Harold S. Osborne, retired chief engineer of the American Telephone and Telegraph Company, received the Howard Coonley Medal for "great service in advancing the national economy through voluntary standards." He was cited specifically for his work as president of the International Electrotechnical Commission.

Many critical shortages of equipment during World War II were not true shortages, Colonel Joseph R. DeLuca, USAF, staff director for cataloging, Department of Defense, told the Conference. "With our pipelines filled with tons of supplies, we still had shortages," he said. "Actually, these items were in our own pipelines without our knowledge because of lack of identification, malidentification, or different identifications for the same item between departments. Thus, we created waste, inefficiency and sharp risk of equipment failures. Further, we had a minimum of support capabilities between our pipelines for effective supply support to combat operations." In order that such conditions will not happen again, the Department of Defense has initiated an all-service cataloging program. Its purpose is to "establish a uniform identification language to support more effective logistics management."

Full participation of Government in ASA work was asked by Standards Council Chairman Arthur S. Johnson.

He invited all Government departments to follow the Defense Department's lead in removing all restrictions on Government representatives serving on committees of the American Standards Association. At the same session, Lewis Ortega, Division of Economic Research, Organization of American States, told the conference that the implementation of a standards program for the 21 American republics would have tremendous significance to the more than 300 million people of these countries. E. J. Overby, Director of the Cotton Division, Agricultural Marketing Service, U. S. Department of Agriculture, spoke to the conferees on the importance of international standards as illustrated by their application to cotton.

The opportunity to join with ASA in cosponsorship of the Sixth National Conference on Standards was welcomed by the National Bureau of Standards. The Bureau's active role in the growth of industrial standardization in this country is exemplified by its history. Work on standard practices and safety codes began in the early years of this century. By 1920 the Bureau had agreed to sponsor seven codes under the old American Engineering Standards Committee, the predecessor of the American Standards Association. Today the Bureau is sponsor under ASA procedure of the codes

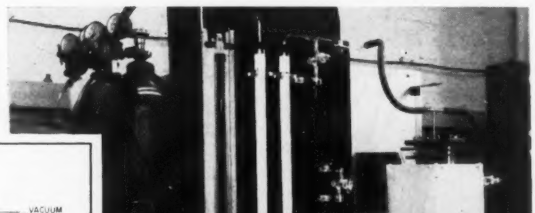
for electrical safety; protection against lightning; protection of head, eyes, and respiratory organs; logging and sawmills; industrial use of X-rays; elevators, dumbwaiters, and escalators; specifications and methods of test of safety glass; electrical fences. In addition, a number of other ASA projects are sponsored by NBS. In all, ASA has 248 committee assignments distributed among the Bureau Staff. This cooperative roll stems from one of the Bureau's important functions as set forth by Congress: "Cooperation with other Government agencies and with private organizations in the establishment of standard practices, incorporated in codes and specifications."

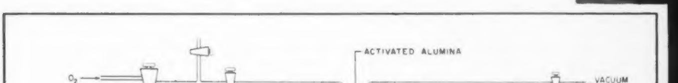
A special feature of the Conference was a tour of the National Bureau of Standards in Washington. Some 200 delegates visited 12 laboratories selected to present a cross section of the Bureau's standards and research activities. On exhibit were the vault where the National Standards of Length and Mass are kept; the laboratory where extremely precise electrical measurements are made; the Bureau's high-speed electronic computer, SEAC; a laboratory where standard samples of metal are analyzed; and a laboratory which is seeking new data on processes within very high-temperature flames. Delegates also saw laboratories for studying metal fatigue, developing hearing and noise standards, and temperature standards near absolute zero; the laboratory where many devices for developing and testing polymeric materials originated; and a laboratory for research on the properties of glass. Two other installations which were visited contained the Bureau's 10 million pound testing machine—the world's highest capacity compression machine, and the large X-ray machines used for research and for the development of basic data on protection from radiation.

Further details on the Conference can be obtained from the Proceedings of the Sixth National Conference on Standards, 70 East 45th Street, New York 17, New York.

The Role of Oxygen in Iron-Enamel Adherence

Atmosphere-mixing and firing apparatus (below right) used to investigate role that oxygen plays in adherence of vitreous coatings to iron. With this apparatus, oxygen content of firing atmosphere can be varied when various enamels are fired onto iron specimens. Insert shows schematic drawing of apparatus.





VITREOUS ENAMELS have long been used on metals to provide protection against corrosion at both normal and elevated temperatures and also to provide a decorative finish. Scientists believe that oxygen in the firing atmosphere plays a role in the adherence of such vitreous coatings to the metal. To obtain detailed information about the adherence mechanism, the Bureau conducted a series of experiments [1] in which the oxygen content of the furnace atmosphere was varied when the same enamel containing varying amounts of an adherence promoter, cobalt oxide, was fired onto iron.

Results reveal that, for optimum adherence, any decrease of oxygen in the furnace atmosphere requires a corresponding increase in the amount of cobalt oxide in the enamel. Enamels containing 3.2 weight percent or more of cobalt oxide develop a weak but definite bond in furnace oxygen concentrations as low as 0.02 mole percent, but when smaller amounts of cobalt oxide are present, a greater oxygen content of the furnace atmosphere is necessary for appreciable bond development.

The study was carried out for the National Advisory Committee for Aeronautics by A. G. Eubanks and D. G. Moore of the Bureau's enameled metals laboratory. It is one of a series of investigations aimed at obtaining a better understanding of the ceramic-to-metal bonding mechanism.

The equipment used consisted essentially of an airtight inductively heated furnace into which metered quantities of oxygen and nitrogen could be admitted at known pressures. The specimens were fired inside the muffle at 1,550° F for a predetermined period. The specimen blanks of ingot iron, 4 by 4 by 0.047 in., were

TABLE 1. *Basic composition of frit used for preparing various ground coats*

Batch composition		Computed oxide composition	
Material	Parts by weight	Oxide	Percentage by weight
Potash feldspar	30.82	SiO_2	51.0
Borax (hydrated)	44.25	B_2O_3	16.1
Flint	30.50	Al_2O_3	5.7
Soda ash	9.16	Na_2O	15.4
Soda niter	5.15	K_2O	3.5
Fluorspar	8.30	CaF_2	8.3
	128.18		100.0

pickled and then coated with the enamel composition. The enamels containing varying quantities of cobalt oxide or cobalt oxide with manganese oxide were prepared according to standard procedures. Adherence of the fired enamel to the specimen was evaluated with the Porcelain Enamuel Institute adherence meter. When used according to the ASTM test procedure, this instrument establishes the fraction of the test area to which the coating continues to adhere after the specimen has been deformed in a prescribed manner.

A coating containing 0.4 percent cobalt oxide developed its best adherence at an oxygen content of 20 mole percent—approximately that of air—while enamels with higher cobalt oxide contents reached their peak adherences at about 5 mole percent of oxygen. It was observed that enamels with larger amounts of adherence oxides do not require as much oxygen in the furnace atmosphere as those with smaller amounts; this observation indicates that oxygen can be supplied from the enamel itself. The conclusion is that the cobalt oxide is in some way supplying or facilitating the supply of some of the oxygen, since the amount of cobalt oxide is the only difference between the coatings. This conclusion is substantiated when the amount of cobalt oxide is plotted against adherence index for specimens fired in low oxygen concentrations. When the curves are extrapolated, they pass through the origin, thus indicating that cobalt oxide-free coatings have an adherence index of zero. With increasing cobalt oxide, however, adherence index increases accordingly.

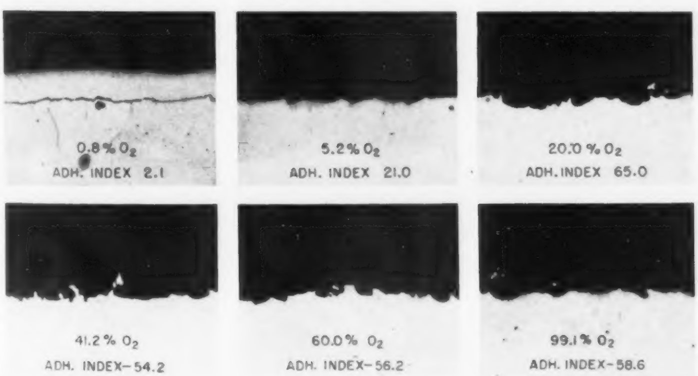
Metallographic sections were prepared of representative specimens. These showed that the adherence increased with increasing roughness of interface between enamel and iron. Earlier investigations at NBS have shown this same type of roughness-adherence correlation.[2] The roughening of the metal has been shown to occur during firing by what is believed to be a galvanic corrosion mechanism.[3] The cobalt ions present in the coating layer tend to plate out of the molten enamel electrolyte onto the more electronegative areas of the iron surface as metallic cobalt. The tiny galvanic cells thus formed cause selective etching of the iron surface if the specimen is fired in an atmosphere containing a sufficient amount of oxygen. Little or no selective etching will occur where there is insufficient oxygen present to promote the corrosion of the exposed areas of the iron. However, the oxygen required for the corrosion process does not necessarily have to come from the furnace atmosphere. If easily reducible oxides are present in the coating layer, then selective corrosion of the iron can still occur even in a furnace atmosphere that is substantially free of oxygen.

There is evidence, however, which indicates that interface roughness does not completely account for adherence: Poor adherence has been observed on very rough interfaces. Also, fairly good adherence has been obtained on alloys without surface roughening. Although the observations made in the present study can be explained on the basis of the galvanic corrosion theory, further work is needed to uncover and to isolate the other active mechanisms in the adherence of vitreous coatings to metals.

[1] *For further technical information, see* Effect of oxygen content of furnace atmosphere on adherence of vitreous coatings to iron, *by A. G. Eubanks and D. G. Moore, NACA Tech. Note 3297; J. Am. Ceram. Soc.* **38,** *223 (1955).*

[2] Relation between roughness of interface and adherence of porcelain enamel to steel, *by J. C. Richmond, D. G. Moore, H. B. Kirkpatrick, and W. N. Harrison, NACA Rept. 1166 (1954) (supersedes NACA Tech. Note 2934); J. Am. Ceram. Soc.* **36,** *410 (1953).*

[3] The galvanic corrosion theory for adherence of porcelain-enamel ground coats to steel, *by D. G. Moore, J. W. Pitts, J. C. Richmond, and W. N. Harrison, NACA Tech. Note 2935 (1953); J. Am. Ceram. Soc.* **37,** *1 (1954).*



Micrographs of coated iron specimens showing effect of oxygen content of furnace atmosphere on surface roughness. Coating contained 0.4 percent cobalt oxide by weight. Coating on specimen fired in atmosphere with 0.8 mole percent oxygen flaked from metal during cutting operations. The section was subsequently nickel plated to preserve the interface. (× 900, unetched)

Dictionary of Color Names

THOUSANDS of color names are in use today among the various branches of art, science, and technology. Modern commerce and industry place great dependence on these names and use them to specify the colors of a large variety of products, from automobiles to women's clothing. Specific identification of color by name is also of great importance in zoology, botany, horticulture, geology, philately, and many other fields.

Over the years, each of these fields has gradually developed its characteristic color vocabulary. Some of these vocabularies are very similar—in fact they borrow from one another—while others are nearly or completely unintelligible to workers in another field. The color world has long needed a dictionary of color names that would correlate the color terms used in different fields and thus provide a common ground for scientists, businessmen, and the general public to compare and identify colors.

The National Bureau of Standards has recently compiled such a comprehensive dictionary with the cooperation of the Inter-Society Color Council (ISCC). The end result of 4 years of research and study, this dictionary not only includes color names from the various fields of application but also relates all the names listed to a common, fundamental system of designation. It lists 7,500 individual color names and defines them in simple, accurate terms that can be easily understood by persons working in different fields. Included are such prosaic color names as *red*, *pea green*, and *dull reddish yellow* along with more fanciful names such as *kitten's ear*, *vamp*, and *French nude*.

Listings are arranged in such a way as to permit anyone to translate rapidly and accurately from one color vocabulary to another. For example, the dictionary shows that *griseo-viridis* (from biology) is equivalent to *serpentine* (fashion), to *mint green* (mass market), and finally to *light green* (ISCC-NBS color designation). The dictionary has been published as NBS Circular 553,[1] *The ISCC–NBS Method of Designating Colors and a Dictionary of Color Names*, by Kenneth L. Kelly and Deane B. Judd.

Earlier dictionaries of color names, which define each color by an actual color swatch, have had limited usefulness in industry because they fail to show the extent of the color range indicated by the name. In the Bureau's color dictionary this defect has been overcome by the use of a method of designating colors through combinations of 21 generic terms—red, yellow, green, light, dark, and so on. In this system all possible colors are divided into 267 groups, each identified by combinations—such as *dark red* or *light green*—of the 21 generic terms. These definitions provide an easily understood, concise, systematic color language composed of simple unambiguous hue names and modifiers.

The terms used to designate colors represent a refinement of a method outlined originally by the Inter-

Color terms from various fields are related in dictionary to common system. Comparison of sample and standard is made through neutral grey shield.

Society Color Council and developed by the Bureau in 1939.[2] These color designations are precisely defined in terms of the standards of the Munsell color system, and the designation for any color may be read quickly and conveniently from color-name charts. It is now possible to determine the ISCC-NBS color designation for a sample whose color is specified in terms of another system of colored samples if the Munsell notations of the reference samples are known.

Circular 553 is made up of four parts. The first part describes the techniques for determining the ISCC-NBS color designations for the colors of different types of samples. Next come the color-name charts from which the designations are obtained. The third part lists all of the color names studied in groups that are synonymous or nearly so; there are 267 groups, one for each of the ISCC-NBS color designations. The last part, which might be called the dictionary proper, is an alphabetical list of all of these color names, together with their designations in the ISCC-NBS system. With each color name is given a code letter indicative of the field in which it is used. After each ISCC-NBS designation defining a color name is a number referring to the section in the third part where all synonymous color names will be found.

All double color names like *turquoise blue* and *synonyms* within one system are cross-referenced. For instance, under "blue" are five pages of cross-referenced blues, from "blue, abstract" to "blue, zephyr." Altogether, there are about 17,000 entries with more than 600 entries under blue alone.

The dictionary of color names should prove very useful to anyone who is looking for a name to describe a certain color. If he wishes to find color names for use in a particular field, such as dyes, philately, or biology, he has only to look for the key letter denoting that field

among the entries in the dictionary. On the other hand, if he has already chosen a color name, he can use the same code letters to determine in what field it has been used before. The manner in which the dictionary is compiled makes differences in meanings of the same color name in different fields immediately evident. Industrial designers and executives who wish to coin new color names should also find this dictionary useful not only as a source of suggestions but also to make sure that the new name does not already have an established meaning.

[1] *Available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $2.00 ($2.50 to foreign countries).*

[2] Method of designating colors, *by Deane B. Judd and Kenneth L. Kelly, J. Research NBS* **23**, *355 (1939) RP1239.*

TABLE 1. *Typical excerpt from the NBS dictionary of color names (column 1, page 133)*

(Each color name is followed by a code letter denoting the source, the abbreviated ISCC–NBS definitions, and numerals referring to previous sections which list the synonymous and near synonymous color names.)

Peacock	TC	m.gB 173
Peacock [Blue] Paon, Pavonine	M	d.gB 174
Peacock Blue	P	d.gB 174
Peacock Blue	R	s.gB 169
Peacock Blue	S	s.gB 169
Peacock Blue	T	s.gB 169, m.gB 173
Bright Peacock Blue	T	brill.gB 168, s.gB 169
Brilliant Peacock Blue (same as Brilliant Blue).	T	s.gB 169
Dark Peacock Blue	T	s.gB 174
Deep Peacock Blue	T	m.gB 173, d.gB 174
Vivid Peacock Blue	T	s.gB 169

In this listing, gB=greenish Blue, m.=moderate, d.=dark, s.=strong, brill.=brilliant, and TC=Textile Color Card Association Standard Color Card, M=Maerz and Paul's Dictionary of Color, P=Plochere Color System, R=Ridgway's Color Standards and Nomenclature, S=Postage-Stamp Color Names, and T=Taylor, Knoeke, and Granville's Descriptive Color Names Dictionary.

Microscopy of Ceramics and Cement

FOR 75 years the petrographic microscope has been the most important tool used for identifying and classifying the mineral constituents of the earth's crust. However, only within the last 20 years has it been used to study chemical reactions and their products in the field of ceramic technology. The first book published in this field, "Microscopy of Ceramics and Cements" (Academic Press, 1955, $7.50), was written by Dr. Herbert Insley, formerly Chief of the Mineral Products Division, National Bureau of Standards, and Dr. Van Derck Frechette, Professor of Ceramic Technology of New York State College of Ceramics. The 286-page publication, which includes 98 photographs plus a color chart, adds significantly to the scientific literature. It is a highly desirable textbook and well documented reference book.

The petrographic microscope technique makes use of polarized light to measure various optical properties of nonopaque solids. The book's first three chapters describe the microscope equipment and review in tabular form the principles of optical mineralogy. Microscopic preparation techniques, manipulation, and quantitative analysis are covered in the following two chapters.

The remaining 10 chapters cover in detail the petrographic examination of various commercial mineral products—their raw materials, the finished product, and the various manufacturing problems. For example, in the process of making silica brick for glass or steel-making furnaces, quartz (SiO_2) is heated and may undergo any one of a number of mineralogical changes. The quartz can invert to some other crystallographic form. It can melt or it can react with associate impurities. The reaction products have their own unique optical properties and can be identified by means of the petrographic microscope.

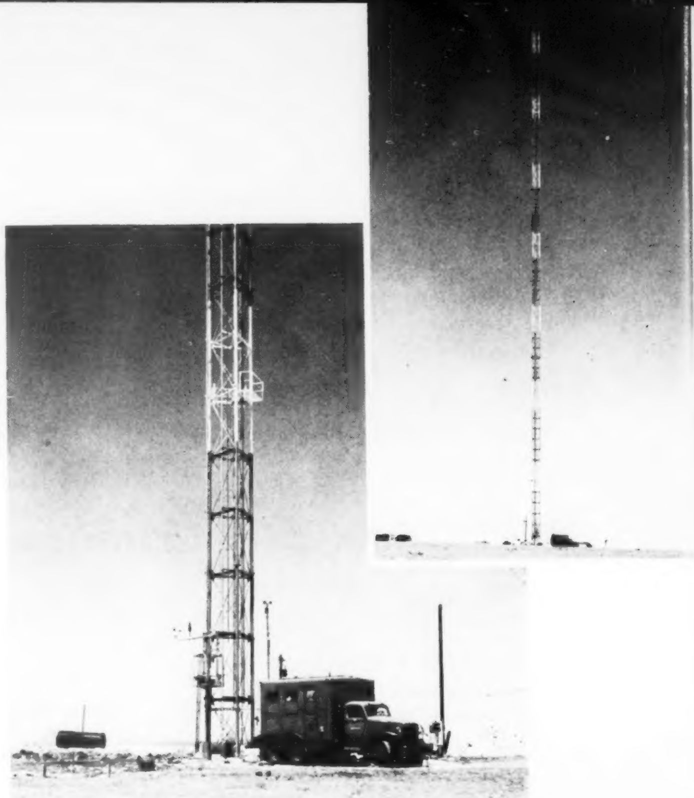
Another technique, discussed in chapter 6, describes how the physicochemical relations of various ceramic raw materials are revealed by microscopic examination supplemented by chemical and X-ray data. Similar petrographic descriptions are given in the chapters dealing with whitewares, refractories, glass, cements, porcelain enamels, structural clay products, foundry sands, and industrial slags. H. N. Baumann, Jr., of the Carborundum Company contributed a chapter on abrasives.

Much of the work recorded in the chapter on cements stems from research conducted at NBS by Dr. Insley for which he received an international reputation as a ceramic petrographer. In addition to its value to ceramic petrography this new book contains basic data on the high temperature physics and chemistry of oxide and silicate materials.

Petrographic (polarizing) microscope being used to determine index of refraction of glassy and crystalline phases in cement clinker. In this setup a sodium vapor lamp provides monochromatic light. Constant temperature bath and refractometer (left) allow a more precise determination of refractive indices. The microscope is equipped with a 5-axis universal stage to orient crystallographic axes.

Forward Scatter of Radio Waves

This is the second and concluding installment of a general report on NBS investigations of forward scatter. Part I, dealing principally with ionospheric forward scatter, appeared in the January issue.



The 500-foot tower at the Haswell, Colo., receiving station, the upper part of which is within radio line-of-sight from Cheyenne Mountain, provides facilities for making simultaneous observations of the meteorology associated with tropospheric propagation, within the radio horizon and just beyond. Meteorological instruments at various heights on the Haswell tower sample air temperatures, pressure, and humidity, from which is computed the refractive index. Scattering occurs when radio waves strike irregular patches, or "blobs," which have a refractive index different from the surrounding atmosphere.

Part II.

Tropospheric Forward Scatter

UNTIL fairly recently, distances much beyond the horizon of a radio transmitting antenna were considered too great for useful communication links at frequencies above 100 megacycles per second, and distances less than 1,000 miles were considered too short for good ionospheric propagation. It is just this range of distances which is important in the application of forward scatter techniques.

For the propagation paths between 600 and 1,200 miles, only the ionosphere will support measurable scatter signals. However, for distances shorter than about 600 miles and at frequencies above 100 Mc, observed scatter signals are tropospheric. The usefulness of the ionospheric scatter mechanisms ceases at about 60 Mc, while tropospheric propagation promises to be useful for communication purposes from 60 Mc up to frequencies exceeding 10,000 Mc.

Like ionospheric scattering, tropospheric scattering is caused by small inhomogeneities in the atmosphere. However, in tropospheric scattering the incident radio energy does not affect the electrical properties of the medium (except in the centimeter-wave region, where absorption effects are important). Thus, in contrast to ionospheric scattering, tropospheric scattering is not very frequency-sensitive.

At frequencies above 50 Mc, climate, weather, and terrain irregularities play principal roles in determining the strength of a tropospheric signal and the distance it will be propagated. Above 1,000 Mc (or below a wavelength of 30 cm), effects of atmospheric absorption become apparent; and at wavelengths of a fraction of a centimeter atmospheric absorption is by far the most important factor in the transmission loss or attenuation between transmitting and receiving antenna terminals. Radar meteorology makes good use of these absorption phenomena.

World War II accelerated development of techniques and applications for the portion of the radiofrequency spectrum above 50 Mc, which include radar, aircraft communications, navigational and guidance systems for aircraft, ground-to-ground radio relay systems, a new system for broadcasting using frequency modulation, television, and many other services. At the close of the war the Central Radio Propagation Laboratory was established at the National Bureau of Standards to centralize and coordinate radio propagation research. Since then, and particularly during recent years, several

Government agencies have requested the aid of CRPL with problems of frequency allocation in the VHF and UHF bands. Examples are the request by the Radio Technical Commission for Aeronautics for guidance in the allocation of air-to-ground communication facilities, the requirements of the Federal Communications Commission for additional information regarding propagation in the UHF–TV band, and a recent request from the Air Navigation Development Board for a study of the propagation factors affecting the expected coverage of tactical air navigation (TACAN) facilities on a country wide basis.

Current interest in tropospheric forward scatter is due in part to the economic advantages of long-distance radio relays, which eliminate a great many expensive relay stations. Many advantages accruing from basic research in this field by NBS and other laboratories come from an increased understanding of propagation. For instance, determination of random phase variations of signals on line-of-sight propagation paths at VHF and UHF reveals some of the limitations imposed by the propagation medium on accurate direction finding systems. Also, quantitative estimates of long-term and short-term time variability—such as fading ranges, fading rates, and signal continuity—are essential to the proper design and allocation of UHF navigation facilities.

The systematic study of tropospheric forward scatter includes not only conventional techniques but also advanced concepts designed to explain and define observed scatter phenomena. NBS activities in the field include investigations of such quantities as transmission loss, fading rate, fading range, phase variations, angular distance, obstacle gain due to diffraction, and path antenna gain. This work has been sponsored by the Army Signal Corps and the Air Force.

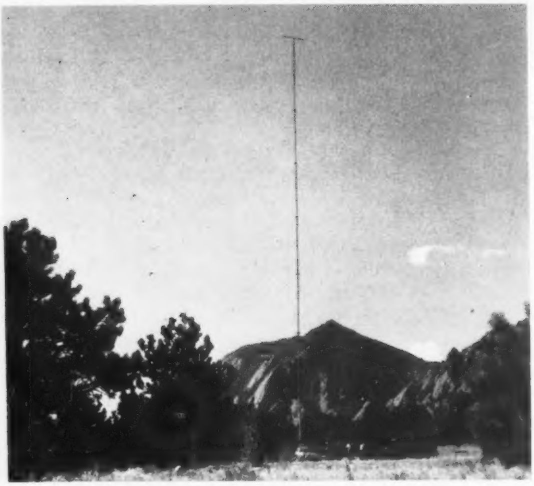
Transmission loss is defined as the ratio of power available from the receiving antenna to the power radiated from the transmitting antenna. This quantity has been used since 1952 to record the results of experimental and theoretical investigations at NBS because one of the characteristics of scatter propagation is that the system will not realize the gain of the antennas. Therefore the usual specification of field strength in terms of effective radiated power is likely to be misleading.

Fading rate, the number of times per minute that the envelope of a received field crosses its median level with a positive slope, is a useful quantity in studying propagation either by diffraction or by scatter. Fading may conveniently be classified into long-term and short-term variations of transmission loss. Long-term variations are caused by slowly varying changes in the propagation medium such as changes in the intensity of turbulence in the troposphere. Short-term changes are attributed to phase interference among simultaneously occurring modes of propagation, that is, to multiple path effects. Recent work has indicated that fading rates within this line of sight are independent of frequency but depend upon the number of atmospheric inhomogeneities or "blobs" that cross the propagation path each minute.

Instrumentation has been developed to measure variations in the phase difference of waves traveling in a single path and of waves traveling in multiple paths. For a single path, variations are measured at the two ends of the path, while for a multiple path the variations in the phase difference between the waves arriving over the first path and those arriving over an adjacent path are measured simultaneously. In addition, instrumentation has been designed to measure the very small changes in the amplitude of the received field which occur within the radio horizon. Use of these two types of instrumentation is expected to permit evaluation of the parameters which are important in the interpretation of scatter mechanisms, particularly where the instrumentation is used in connection with microwave refractometers and other meteorological equipment under a variety of atmospheric turbulence conditions.

Certain geometrical parameters have been found use-

High-power continuous-wave transmitters located on Cheyenne Mountain, Colo., have an unobstructed transmission path extending several hundred miles out into the plains.



Mobile recording units with a variety of equipment, including a 100-foot telescopic mast, have been used for making measurements in the plains, foothills, and mountainous regions of Colorado. With this equipment it has been possible to study more thoroughly the effects of irregular terrain on VHF and UHF propagation.

ful in developing methods for predicting transmission loss under a variety of conditions. One of the most important of these is the angular distance, θ, defined as the angle in the great circle plane between the horizon rays from the transmitting and receiving antennas as determined for a radio standard atmosphere—that is, using an effective radius of the earth 4/3 times its actual value. Over a smooth spherical earth the angular distance is equal to the distance between the radio horizons of the transmitting and receiving antennas divided by the effective radius of the earth. The difficult problem of defining antenna height over irregular terrain becomes less important when angular distance is used as a parameter.

Fading range is the difference in decibels between the instantaneous transmission loss levels that are exceeded 90 percent and 10 percent of the time during a short period such as one hour. It is convenient to consider received VHF and UHF fields as consisting essentially of two components. One has a slowly varying amplitude and results from some mechanism such as ground wave propagation within the horizon or diffraction accompanied by ducting or reflection from elevated layers in propagation beyond the horizon. Another component has a rapidly fluctuating amplitude and results from atmospheric scattering. In developing scattering and diffraction theories it is important to be able to separate out these two mechanisms from the observations.

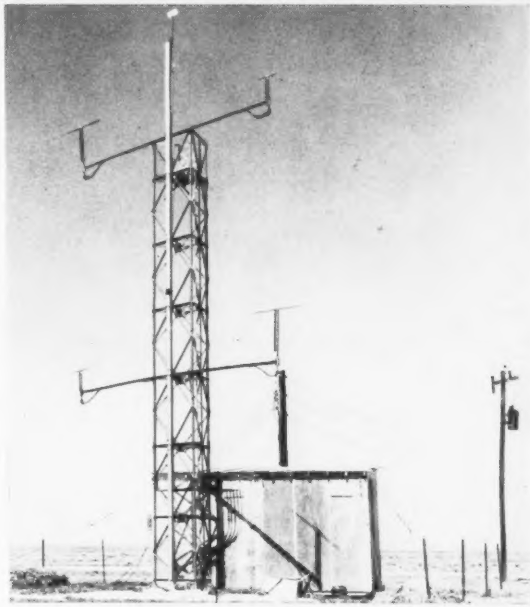
The use of angular distance in estimating transmission loss and fading range for propagation through a turbulent atmosphere over irregular terrain has provided a set of prediction formulas which agree very closely with observed 6-month median values. The observations include some 136,000 hourly median values of transmission loss, over 122 propagation paths at frequencies ranging from 66 to 1,046 Mc.

Large obstacles which act like single knife edges in ground-to-ground propagation paths can effectively reduce transmission loss and fading below the amount observed with the forward scatter mechanism. Measurements have been made on several paths approximately 100 miles long, one of which passed over Pike's Peak at an elevation of 14,109 feet above sea level. When transmission was directly over the summit of the Peak, the signals were much stronger than when the path passed on either side. Very little fading was observed in this location.

Transmission loss over a knife edge is systematically less than that for propagation over a sphere, indicating the desirability of developing a method of calculation applicable more generally to obstacles of intermediate shapes. Such a method has been developed, depending upon the fact that transmission loss over a smooth sphere with distance and angular distance constant decreases rapidly as the effective radius of the sphere becomes less.

NBS research on tropospheric forward scatter has been continuous since January 1949, when a large-scale program of field strength measurement of FM and TV stations was initiated. Within 2 years the program had grown under the direction of CRPL with the assistance of the Federal Communications Commission, several universities, and other organizations, until at the the end of 1951 long-term measurements were being obtained by subcontractors over a hundred propagation paths scattered throughout the country. Data were

Transmissions are made on five frequencies in the VHF and UHF ranges from two locations, one at the summit and this one at a lower elevation on Cheyenne Mountain.



Typical receiver installation used in tropospheric scatter research. This particular site, including tower, antenna, receiver, and recording equipment, is located at Kendrick, Colo. The installation operates unattended.

supplied under contract to CRPL in the form of hourly median values of field strength and were recorded over some paths for several years. At the present time, more than half a million punched cards are available containing these data.

By November 1951, preliminary measurements had been made at 1,000 Mc out to a distance of several hundred miles from the NBS Cheyenne Mountain Field Station in Colorado. This station had been established in June 1950 to determine tropospheric propagation characteristics within, near, and far beyond the radio horizon. At about the same time the Bureau's Tropospheric Propagation Research Section moved to Boulder, Colorado.

Facilities

Facilities of the Cheyenne Mountain experiment include high-power continuous-wave transmitters on five frequencies, from 92 to 1,046 Mc. Continuous recordings have been maintained for long periods at four fixed receiving stations located up to 226 miles from the transmitters, and for shorter periods at semifixed installations at Anthony, Kansas, and Fayetteville, Arkansas. These two installations are 393 and 617 miles, respectively, from Cheyenne Mountain. The location of one of the transmitting antennas, more than 3,000 feet above local terrain, provides a simulated "air-to-ground" communication link. The area is ideal for meteorological studies because of its heterogeneous meteorology.

Facilities for determining the meteorology associated with tropospheric propagation in the Cheyenne Mountain experiment include a 500-foot tower at Haswell, Colorado, just beyond radio line-of-sight from Cheyenne Mountain; and portable equipment for determining pressure, temperature, and humidity with conventional recording devices along the propagation paths. A resonant cavity microwave refractometer developed at the Bureau is used on the Haswell tower and in aircraft flights through the area to determine the refractive index of the atmosphere as a function of time and position in space. The refractive index is regarded as the most important of the meteorological parameters expected to correlate radio and weather phenomena.

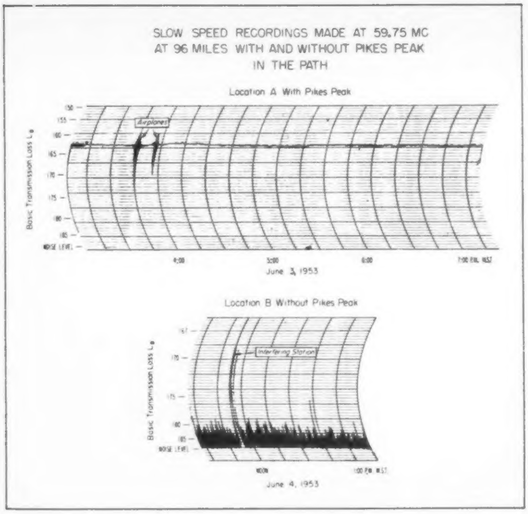
Several mobile recording units are available for making measurements in the plains, foothills, and mountainous regions of Colorado. With this equipment, including a 100-foot telescopic mast, it has been possible to investigate more thoroughly the effect of irregular terrain on VHF and UHF propagation. In general, higher propagation loss and greater ranges of variability are associated with the foothills terrain than with the plains, and correlations between observations of transmission loss tend to be mostly dependent upon the degree of separation of the propagation paths and much less dependent upon differences in frequency.

Meteorological and radio data have been correlated over many paths in addition to those in Colorado and Kansas. A meteorological microfilm library, containing all North American surface and constant-pressure charts for 1946 through 1951, provides a ready check for radio data due to unusual meteorological conditions. Also, it forms the basis for correlation work with observed radio transmission loss data. Following up analyses which prove there is a significant correlation between surface refractivity and radio transmission loss along a path, 4,500,000 punched cards were obtained from the Weather Bureau to supply needed information about surface refractivity over the country.

Measurement of radio transmission loss and meteorological conditions concurrently over the same path and over a wide range of frequencies makes it possible to estimate missing values from the information obtained with the large amount of 100-, 200-, and 1,000-Mc data. The wide frequency range and carefully controlled conditions of the Cheyenne Mountain experiment have provided accurate information for the development of scattering and diffraction theory, and have added to the large amount of data required for adequate statistical description of the behavior of tropospheric propagation through a turbulent medium and over irregular terrain.

Part III. Causes and Theory of Propagation by Scattering Due to Turbulence

The Bureau's experimental research on tropospheric and ionospheric scatter mechanisms has been accompanied by a study of the causes and theory of scattering due to turbulence. This subject involves many different



Continuous recordings of the transmissions from Cheyenne Mountain at receiving stations in Colorado, Kansas, and Arkansas, together with meteorological data taken along the transmission path, give a measure of tropospheric propagation characteristics within, near, and far beyond the radio horizon.

aspects which must be pieced together. Some are related to the dynamics of the turbulence itself: What produces the density fluctuations involved? What are their amplitudes and their sizes? Can their distribution be obtained deductively without special hypotheses from general meteorological information such as distribution of winds, temperature, and humidity? Other important aspects are related to the electromagnetic theory: how the scattered field is affected by the distribution of fluctuations in the atmosphere. Relatively little has been published on these problems, and it is only very recently that a satisfactory theory has been achieved. This account gives the principal results of recent NBS work, still in great part unpublished.

The turbulence, more or less intense, which exists permanently in the atmosphere produces slight fluctuations of density. This causes the refractive index to vary by very small amounts at each point of the atmosphere, and these variations produce scattering.

In the troposphere, the refractive index is a function of temperature and of water vapor content. In the ionosphere it is a function of the electron density. If the density of the air varies by small amounts, these quantities will vary and in turn will cause fluctuations of refractive index.

The Bureau's recent studies [1] have shown that the density fluctuations are due to the *vertical transport* of masses of air (blobs) by the turbulent motions. Their amplitude depends on the difference between the normal (or mean) temperature gradient of the atmosphere and the adiabatic gradient (the theoretical gradient when there is negligible heat exchange). This effect is more important in the ionosphere than in the troposphere. In the ionosphere it is accompanied by fluctuations due to the vertical transport of the electrons, which have a distribution of their own different from the air density distribution.

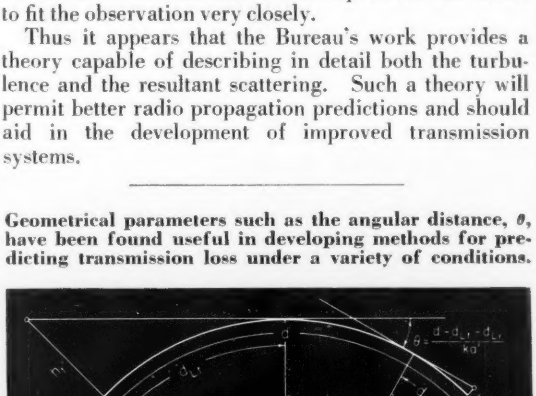
[1] See Aerodynamical mechanisms producing electronic density fluctuations in turbulent ionized layers, *by R. M. Gallet, Proc. IRE* **43,** 1240 (1955).

Also required is an accurate mathematical description of the fluctuations which can meet the test both of theory and experimental observations. There are two different mathematical descriptions of a field of these random fluctuations, one known as the autocorrelation function, the other called the statistical spectrum. These two descriptions are in principle mathematically equivalent, but the problem was to derive the correct expression. In previous works the correlation function was principally used, but it was chosen for mathematical convenience without full regard for the dynamics of the turbulence. However, taking the above considerations into account leads more naturally to the spectrum. The result finally obtained was found in remarkable agreement with the observations. It was also found that the "scale" of the turbulence (about the dimension of the largest blobs) can be obtained from the shearing effect of the differences of winds.

From the spectrum of the refractive index fluctuations and from the electromagnetic equations, it was possible to obtain the scattering coefficient—that is, the formula giving the power scattered as a function of the frequency and of the angle of scattering. Naturally a correct expression must furnish the same results with the correlation function, corresponding to the spectrum, through a different set of equations. By applying the spectrum derived from the study of the turbulence in this general expression, a coefficient was obtained which could be compared with the very precise observations at hand. The theoretical expression was found to fit the observation very closely.

Thus it appears that the Bureau's work provides a theory capable of describing in detail both the turbulence and the resultant scattering. Such a theory will permit better radio propagation predictions and should aid in the development of improved transmission systems.

Geometrical parameters such as the angular distance, θ, have been found useful in developing methods for predicting transmission loss under a variety of conditions.



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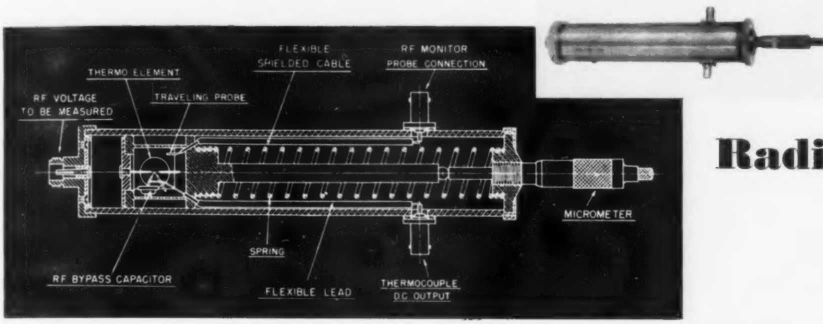
The use of angular distance in estimating transmission loss and fading range for propagation through a turbulent atmosphere over irregular terrain, *by K. A. Norton, P. L. Rice, and L. E. Vogler.*

Stable Radiofrequency Voltmeters



Drawing and photo of attenuator-thermoelement (AT) voltmeter developed by NBS that has superior short-time and long-time calibration stability. It consists of a continuously adjustable waveguide-below-cutoff piston attenuator and a freqency insensitive thermoelement to monitor (by means of a d-c millivoltmeter, not shown) the attenuator output. Traveling piston of attenuator houses thermoelement and a built-in rf probe for calibrating one rf level of voltmeter. Only this voltage level needs to be calibrated at a given frequency; all other voltages are then accurately known.

A VERY STABLE type of radiofrequency voltmeter, known as an attenuator-thermoelement or AT voltmeter, has been designed by M. C. Selby and L. F. Behrent of the Bureau's Boulder Laboratories. Unlike instruments now available, AT voltmeters maintain a calibration stability well within the accuracy of the original calibration—about 1 percent over most voltage and frequency ranges—for a year or longer.

AT voltmeters can be used to measure rf voltages from 0.1 to several hundred volts at frequencies up to about 1,000 megacycles per second. Although rf voltages within this range can be accurately measured and standardized by other means, it is difficult to find voltage-measuring instruments that can hold their calibration for a reasonable length of time, such as a year. In this respect, present-day voltmeters using thermionic or crystal diodes are generally not reliable as laboratory reference standards. Even under most careful treatment the uncertainty in their calibration is about 10 percent and may frequently be as high as 20 percent.

Experience to date indicates that the most stable elements suitable for calibrated-type rf voltmeters are thermoelements, waveguide-below-cutoff or capacitive-type attenuators, capacitive voltage dividers, and some well-constructed resistive attenuator pads.

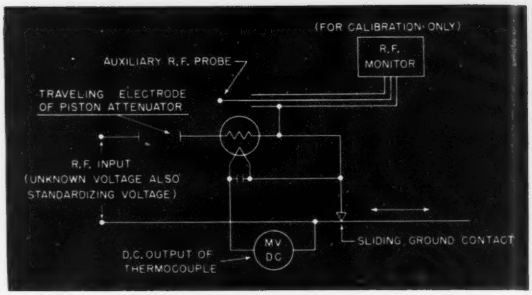
One of the high-frequency AT voltmeters, having superior short-time and long-time calibration stability, consists of a continuously adjustable waveguide-below-cutoff piston attenuator, a thermoelement, and a d-c millivoltmeter. It was designed for high voltages at the higher frequencies. The traveling piston of the attenuator houses the thermoelement and a built-in auxiliary rf probe. This probe is used to calibrate the AT voltmeter in terms of a primary standard bolometer bridge. The bridge output is approximately 1 volt, which is insufficient for direct calibration of the voltmeter over an appreciable part of the frequency range in question. Because of the intentionally introduced high insertion loss of the attenuator, at 5 Mc for example, it is necessary to apply more than 300 volts to the voltmeter for a sufficiently large output of the thermoelement, whereas 1 volt would be adequate at 900 Mc. The probe provides means to calibrate the voltmeter with 1 volt or lower voltage levels at all frequencies. An rf receiver is connected to the probe output, and a standardized rf voltage is applied to the AT voltmeter. The receiver indication is noted at the minimum attenuator setting. The rf voltage is then increased to a value V_0 at which the millivoltmeter is indicating a calibration reference output of the thermocouple. Attenuation in the AT voltmeter is then increased to reproduce the original indication on the receiver. With both the change in attenuation and the standardized voltage known, the magnitude of V_0 applied to the AT voltmeter is computed. Only one voltage level, V_0,

needs to be calibrated at a given frequency; all other voltages at this frequency in the range of the instrument are then accurately known.

Another design, having relatively close electrode spacing, behaved over part of its range like a continuously adjustable capacitive attenuator and required extensive calibration. Its voltage range was about 100 to 1. Single AT meters, utilizing both the capacitive and the waveguide-below-cutoff ranges as well as the range of the thermoelements, will have an over-all voltage range of 1,000 to 1 at all frequencies in question. The upper voltage limit would diminish with increasing frequency; for example, it would be about 900 volts at 100 Mc and about 300 volts at 500 Mc. Nomographs designed for the AT voltmeters enable their quick application, either as reliable transfer standards or as working instruments.

Still another design is the capacitive "single-frequency" rf voltmeter. The essential difference between this design and those described in the previous paragraphs is a fixed capacitive attenuator. Although designed for a single frequency, it may be calibrated and used over a range of frequencies.

Several AT voltmeters may be required to cover the entire voltage and frequency range of some of the VT

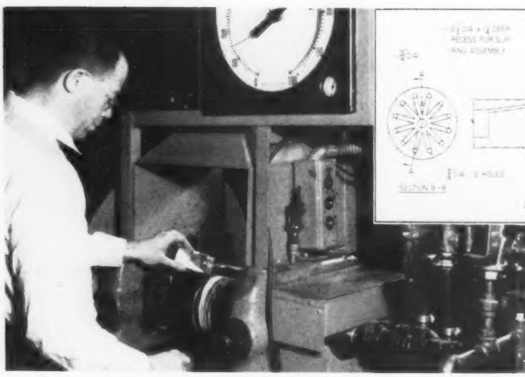


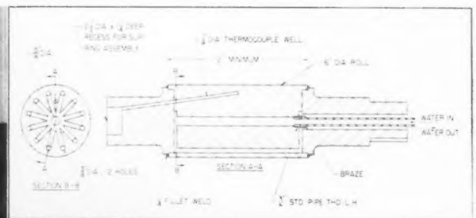
Schematic of the AT voltmeter.

voltmeters on the market because their response is frequency sensitive, except in the case employing resistive pads. However, construction is relatively simple and quite economical. AT-voltmeter input impedance approaches that of commercial VT voltmeters except when resistive pads are used.

AT voltmeters are particularly suitable and at present practically indispensable, as secondary reference standards for any laboratory requiring voltage accuracies better than 10 percent.

Temperature Control for Mixing Rubber Compounds





An operator mixes rubber compounds on laboratory mill rolls developed at the Bureau. The temperature recorder-controller (above machine) operates from a thermocouple in one roll, regulating the temperature of the water flowing through the rolls by means of the three valves at right. Sectional drawing shows how circulating coolant enters central cavity (right) and returns through 12 parallel ducts 5/8 in. from surface. Temperature control system of roll uses a thermocouple sensing element 1/4 in. from roll surface to detect changes in temperature. Surface temperatures can be automatically controlled to within 7° F.

THE BUREAU has developed special temperature-controlled steel rolls for laboratory mixing of rubber compounds. Designed by F. L. Roth, G. E. Decker, and R. D. Stiehler of the Bureau's rubber laboratory, the rolls use an automatic control system [1] based on a thermocouple sensing element to maintain constant roll surface temperature. Development of the rolls was sponsored by the Federal Facilities Corporation, Office of Synthetic Rubber, in connection with the Government synthetic rubber program.

Small-scale mills are widely used by testing laboratories to mix rubber compounds. However, their limited size (6 by 12 in.) makes temperature control difficult; this has been disadvantageous because the properties of the rubber compound are appreciably affected by mixing temperatures. For example, the Mooney viscosity of GR–S[2] compounds increases as the roll surface temperature increases. Also, the tensile stress versus elongation curves of cured vulcanizates show that stiffness increases and elongation at failure decreases with increasing roll temperature.

The effects of roll temperatures are recognized in the Government specifications for synthetic rubbers and in ASTM standards, both of which prescribe limits for the temperatures of the mill roll surfaces during mixing. Even though these limits permit a range of 18 or 20 deg F in the surface temperature, it is difficult to maintain this temperature control because the rate

of heat transfer through the conventional thick-walled roll is too slow.

In recent years it has become increasingly clear that the mixing temperatures of rubber compounds must be controlled if reproducible values for their properties are to be obtained. The Bureau therefore made an intensive study of roll temperature control which resulted in the present roll design.

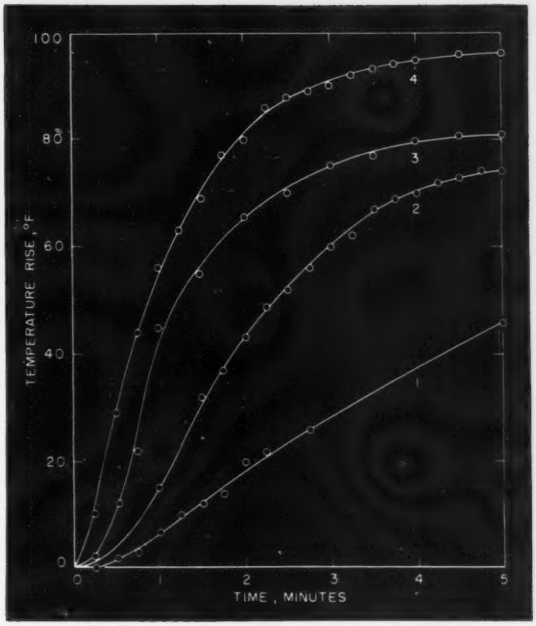
Laboratory mill rolls are used in pairs; the space between them can be adjusted to control the thickness of the rubber. The rolls turn at different speeds and thus produce a shearing action on the rubber compound. This action is used in introducing into the rubber the various ingredients, such as carbon black and sulfur. Temperature control is especially difficult at the time of the addition of ingredients during mixing.

Most rolls are constructed with a central cavity 1¼ to 2 in. in diameter. Cooling or heating of the roll is accomplished by spraying water or steam against the walls of the cavity. Since there are two or more inches of steel between the cavity walls and the outer surface of the roll, the rate of heat transfer is too slow to control the temperature within a few degrees, particularly when the heat generated by the rubber compound during mixing varies.

The Bureau investigated a special roll in which the diameter of the cavity was increased to 4 in., leaving only 1 in. of metal in the walls. This roll had an increased rate of heat transfer but did not control temperature as precisely as desired. Another mill roll, in which the water or steam travels through spiral cavities near the roll surface, had an improved rate of heat transfer. When an automatic controller was used with each roll, the spiral type could control surface temperatures within a range of about 5° F in mixing soft compounds. However, stiffer compounds requiring more power increased the temperature difference to as much as 30 deg F between the sensing thermocouple and the roll surface.

In the roll eventually developed by the Bureau, the water or steam flows from one end of the roll to the other through a central cavity and returns through 12 parallel ducts ⅜ in. in diameter. The center lines of the ducts are ⅝ in. from the roll surface. A well is provided so that a thermocouple can be placed within ¼ in. of the roll surface. The thermocouple lead wires are connected to sliprings at the end of the roll shaft.

Measurements of temperature changes in the surface of the roll following an abrupt change in coolant temperature show that the rate of heat transfer for the NBS roll is greater than for any of the rolls studied. A mill using these rolls and an automatic temperature control system has been in use at the Bureau for about a year. The automatic controller operates from a thermocouple



Graph illustrates superior heat transfer in NBS mill roll. Curves indicate temperature changes in four different rolls following in increase of 100° F. in temperature of circulating fluid. Curve No. 1, central-cavity roll with a wall thickness of 2 in.; No. 2, central-cavity roll with a wall thickness of 1 in.; No. 3, spiral-grooved roll; No. 4, NBS roll.

in one roll and regulates the flow of water in a closed circulating system by means of three pneumatic diaphragm valves. Two of the valves admit water or steam to respective heat exchangers, and the third proportions the amount of water admitted to the rolls from each exchanger. This system controls the temperature of the roll containing the thermocouple within 2 deg F of the desired temperature during the mixing process. The temperature of the other roll may vary by as much as 7 deg F from the control point when there is a rapid change in the amount of power required. However, this variation could be reduced to about 2 deg, if necessary, by the use of a separate control system for each roll.

[1] *For further technical details, see* Temperature control during mixing of rubber compounds, *by F. L. Roth, G. E. Decker, and R. D. Stiehler, Rubber World,* **132**, 483 (1955).

[2] *GR-S is the synthetic rubber made by copolymerizing butadiene and styrene.*

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February 1956 Issued Monthly Vol. 40, No. 2

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Contents

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RP2642. A calorimeter for measuring the power in a high-energy X-ray beam. John McElhinney, Bernard Zendle, and Steve Domen.

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Patents

(The following U. S. Patents have been granted to NBS inventors. Assignor to the United States of America as represented by the Secretary of the Department noted in parentheses.)

No. 2,722,602. November 1, 1955. Saturable reactor controlled delay multivibrator. Myron G. Pawley. (Navy.)

No. 2,724,269. November 22, 1955. Apparatus for measuring flow. Henry P. Kalmus. (Commerce.)

No. 2,727,143. December 13, 1955. Means for minimizing pulse reflections in linear delay lines loaded with a nonlinear load. Ralph J. Slutz. (Commerce.)

No. 2,727,605. December 20, 1955. Electrodynamically operated clutch and brake. Jacob Rabinow. (Army.)

No. 2,727,697. December 20, 1955. Vibratory ball mills. Walter K. Stone. (Commerce.)

U. S. GOVERNMENT PRINTING OFFICE: 1956

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